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The phenomenon of Energy Concentration in High Energy Families

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Abstract

The lateral energy distribution of super-high energy family events are studied with emulsion chambers at Mt. Kanbala and compared with the results of Monte Carlo simulation. Analysis indicates that a phenomenon of energy concentration exists in super-high energy families.

Key words: Emulsion chamber experiment, Gamma family, Energy concentration

1 Introduction:

High energy γ- family and γ-h family events with total visible energies $\Sigma E_{tot} \geq 100$ TeV have been studied with large scale emulsion chamber experiments at high mountain during recent 20 years. There are different views on the mechanism of super-high-energy nuclear interactions among different experimental collaborations in the world. The simulation calculations are based on different physical hypotheses, but results obtained from different models are consistent with experimental data. So it is difficult to decide which model is more reasonable for describing the emulsion chamber experiments at present. There is a phenomenon of energy concentration in hadronic families with total visible energies $\Sigma E_{tot} \geq 100$ TeV reported by Chacaltaya and Pamir Collaboration [1]. The fraction of the shower energies ΣE $(r \leq 10$ mm) in the region of radius $r \leq 10$ mm (or $r \leq 5$ mm) around the center of the hadronic family is over 90% of the total visible energies of the hadronic family. The lateral energy distribution is difficult to explain the simulation results based on the 5 different hypotheses.

We attempt to study this phenomenon with data of Kanbala emulsion chamber experiment. The experimental results indicate that the phenomenon of energy concentration exists in both of the hadronic and γ family events with total visible energies $\Sigma E_{tot} \geq 100$ TeV.

2 Experiment:

The main purpose of the emulsion chamber experiment at Mt. Kanbala (5500m a.s.l.) is to study the mechanism of high enery nuclear interaction in the energy area

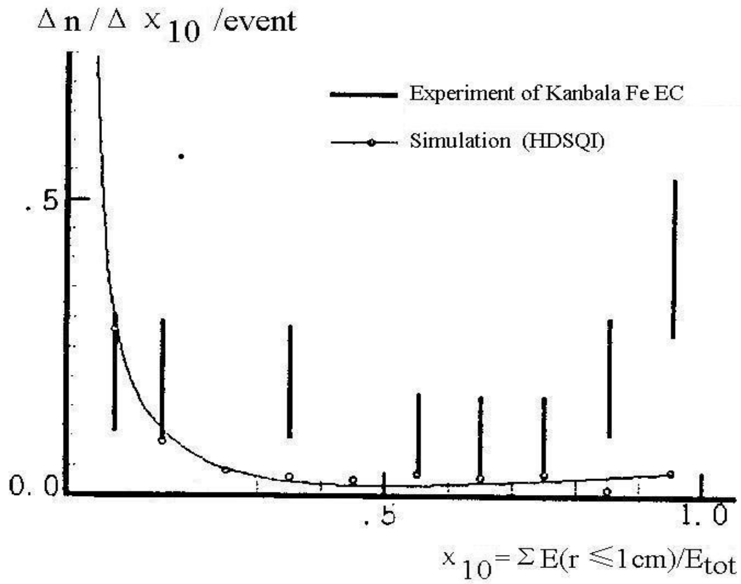

Fig.1. The lateral energy distribution of family events in the Fe emulsion chambers

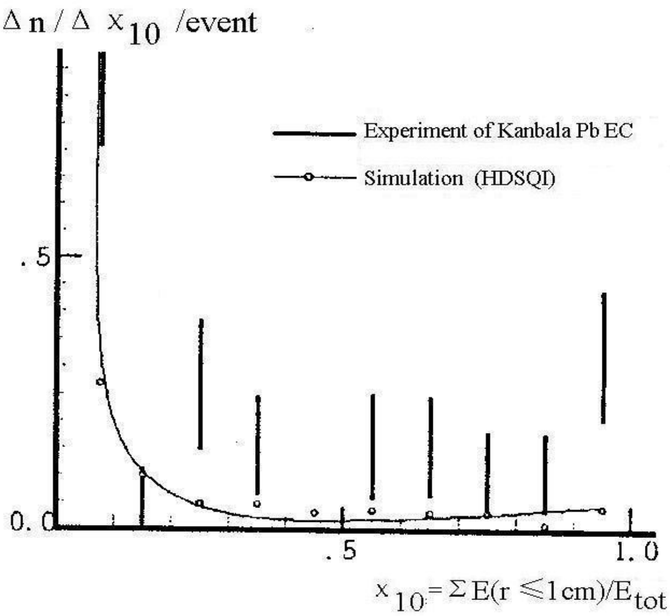

Fig.2. The lateral energy distribution of family events in the Pb emulsion chambers

over the present accelerator experiments. Emulsion chamber is a electromagnetic shower detector which consists of multi-layer lead plates (or iron) and photosensitive materials (x-ray films and nuclear emulsion plates). The space and energy resolutions are x=10-50μm, ΔE/E≈10~20%, the energy threshold of detection is

E_{th}~1 TeV, the details are to be seen in the reference[2]. The distributions of the fraction of shower energies within a circle ΣE ($r \leq$ `10 mm) to the total visible energies ΣE_{tot} of family events with $\Sigma E_{tot} \geq 100$ TeV obtained by the Kanbala emulsion chamber experiment are shown in the Fig.1 and Fig.2. They are consistent with the corresponding distributions obtained by Tamada[1]. The experimental results are compared with the simulation calculations based on the model which is under the assumption of an approximate Feynman scaling in the fragmentation region and the primary composion is heavy-nuclei-dominant[2]. From the experimental results we can see that the fraction of the shower energies in the region within $r \leq 10$ mm is far beyond the simulation for the events with $x_{10} \geqslant 0.9$. It should be noticed that the data we used here are all of the γ- family and γ-h family events with total visible energies $\Sigma E_{tot} \geq 100$ TeV. The events with $x_{10} \geqslant 0.9$ are mainly come from the γ-family events and only 1/4 come from γ-h family events. In the γ-h family events the main contribution is from the γ-rays, and the hadrons are very few. It indicates that the phenomenon of energy concentration is a characteristic feature of high energy nuclear interactions and it is not only for high energy γ-h families.

3 Discussion:

The experiment shows that there are collimated high energy showers exist in the extreme straight forward region of the interactions, the energies of which are over 90% of the total visible energies of the family events. This phenomenon could not be illustrated by the simulation using the model based on the extrapolation of the data of present accelerator experiments. The number of the family events decreases with the increasing of x_{10}, it is due to the energy dissipation is very fast when the particles go through the atmosphere. The phenomenon of energy concentration could not exist in the extreme straight forward region in the Monte Carlo simulation, because the lateral distribution of the secondary particles is wide due to their large transverse moment. This is the reason why there are almost no events in the region $x_{10} \geqslant 0.9$ for the data of simulation calculations.

Let us analyze the phenomenon of energy concentration from the experimental data. Dividing all the events into two parts $\Sigma E_{tot} \geq 500$ TeV and $\Sigma E_{tot} \leqslant 500$ TeV according to the total visible energies of the family events and drawing the same distributions as Fig.1 and Fig.2, the results show that the distributions in the part of $x_{10} \geqslant 0.9$ are still far beyond the simulation results. It seems that the phenomenon of energy concentration still exists when the total visible energies increase, even though in this case the multiplicity of the family events goes higher and the energies of the secondary particles produced in the high energy nuclear interactions disperse.

In order to investigate the phenomenon of energy concentration for the events with lower multiplicities we studied the single uncorrelated showers with energy E $\geqslant$100 TeV. Most of the collaborations only choose the events with $N_\gamma + N_h \geqslant 4$ in the study of family events. These high-energy uncorrelated showers may be regarded as the members of the family in which the low energy showers (E$\leqslant$4 TeV) are not recorded by the emulsion chambers. It seems that these single showers also refer to the events with the phenomenon of energy concentration. There are 9 single showers (in which 2 are hadrons) with energy E$\geqslant$100 TeV in 179 blocks of K5-K8 of Kanbala emulsion chambers. According to the energy spectrum of single showers from the work[3], we can estimate the number of the single showers with energy E$\geqslant$ 100 TeV in the corresponding blocks. There should be 4.8 hadrons and 4.9 γ -rays, it means that there should be ~10 high energy single showers, which is consistent with the stastistics mentioned-above. From the fact that the number of high-energy single showers in experimental data is not beyond the expected one we could estimate the phenomenon of energy concentration is not obvious for the events with low multiplicities

In order to explore the mechanism of energy concentration formed in the high energy nuclear interactions we made simulation calculation, in which the fractions of single diffraction process in the total cross section of inelastic interactions were taken as 19%, 30% and 90% respectively. The results indicated that the single diffraction process displayed only a litle effect on the phenomenon of energy concentration.

From these discussions it can be seen that the energy concentration exists in the high energy nuclear interactions with total visible energies $\Sigma E_{tot} \geq 100$ TeV. It is not obviously deal with the multiplicity of the family events and it does not indicate that the cross section of the single diffraction process increases. Because the phenomenon of energy concentration does not only exits in hadronic families, so it is difficult to be explained by the existence of mini clusters, in which the hadrons are included and their penetration power is very high.

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